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**Joint CERES/GERB Meeting**
**Boulder, Colorado**

# Comparison of Diurnal OLR Cycle from GCM with ERBE Results

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# Motivation

The Diurnal cycle describes the interaction of the atmosphere and surface to solar heating on a time scale at which the details of cloud formation, planetary boundary layer and surface response are important. Because of the non-linearity of the system, if the diurnal cycle is not well characterized, the longer term results are suspect.

As such, the comparison of the diurnal cycle of OLR as computed by a GCM with the results from the precessing Earth Radiation Budget Satellite should reveal much about both the observational results and the model.

# Review of ERBE Results

5 years of Scanner data from precessing ERBS were analyzed to produce Diurnal Cycles of OLR for ERBE 2.5º regions and 1 hour temporal resolution.

- These Diurnal Cycles were resolved into Principal Component Time Histories and EOF maps.

# Procedure

The ERBS provided diurnal cycles for 2.5$^o$ regions from 55$^o$S to 55$^o$N. The GCM provides diurnal cycles for 2.5$^o$ lat x 3.75$^o$ long over the globe. How do we compare so many curves?

We choose to represent the diurnal cycles by use of a basis set so that we can use the coefficients of the terms for comparison.

The most economical basis set is principal components PCs, i.e the diurnal cycles can be expressed to a given accuracy by use of fewer PCs than any other basis set.

# Principal Component Analysis

The diurnal cycle of OLR for a region is defined as the difference of the mean OLR at local time t from the daily average OLR. The diurnal cycle is expressed as

$$y(x,t) = \sum PC_n(t) \times EOF_n(x)$$

We first treat the Model OLR as a data set and compute the PCs and EOFs of this global data set for July.
Then we compute the PCs and EOFs of the Model OLR for Summer and over the ERBS domain, I.e. between 55$^o$S to 55$^o$N in order to compare with the ERBS results.

# Land/Ocean

The diurnal cycle of OLR over land is much greater than over ocean due to the tremendous heat capacity of the oceans. We divide the Globe into land and ocean, so that the variation of OLR over land will not overwhelm that over ocean. More important, the physics of the diurnal cycle differs from land to ocean and the analysis method should permit these differences to show.

We consider first the Model over the complete Globe for July, then the Model for the the ERBS domain for June+July+August and the ERBS results.

# Variances: Land

**Table 1: Variances for Land**

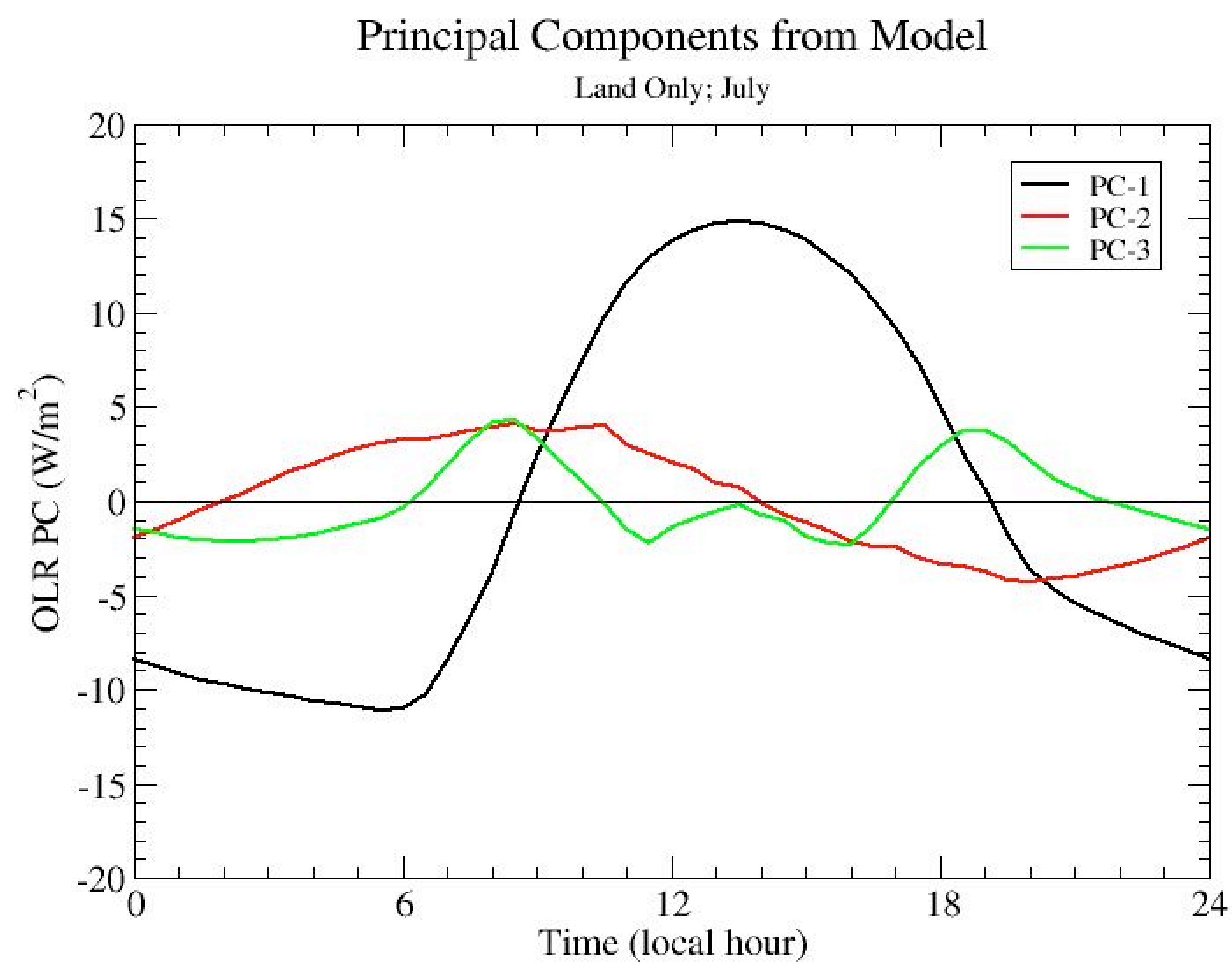
| Order | Model, Global, July | Model, ERBS Domain, Summer | ERBS, Summer |
|---|---|---|---|
| 1 | 0.856 | 0.887 | 0.757 |
| 2 | 0.075 | 0.057 | 0.101 |
| 3 | 0.037 | 0.033 | 0.021 |
| 4 | 0.011 | 0.009 | 0.017 |
| 5 | 0.005 | 0.004 | 0.011 |
| Sum, 5 terms | 0.984 | 0.990 | 0.907 |
| RMS, $W\text{-}m^{-2}$ | 14.7 | 16.2 | 13.3 |

# Discussion of Variances for Land

The model variance for the ERBS domain (55$^o$S to 55$^o$N) is greater than for the Globe. Higher latitudes have a smaller OLR diurnal cycle than do low latitudes.

The model variances converge faster than do the ERBS, indicating that the ERBS OLR diurnal cycles are more varied than the model cycles.

The model RMS for the ERBS domain is slightly higher than the observed RMS.

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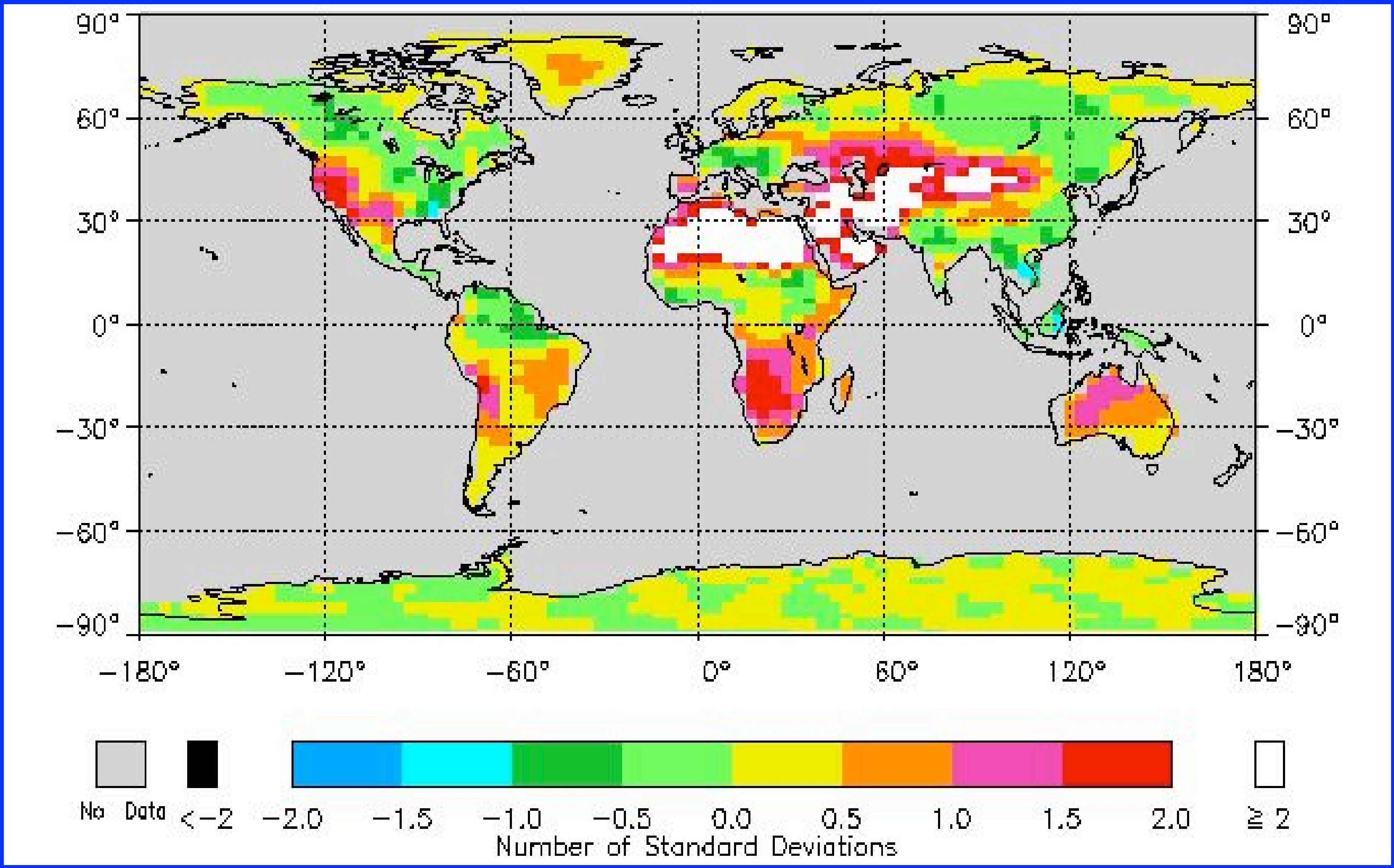
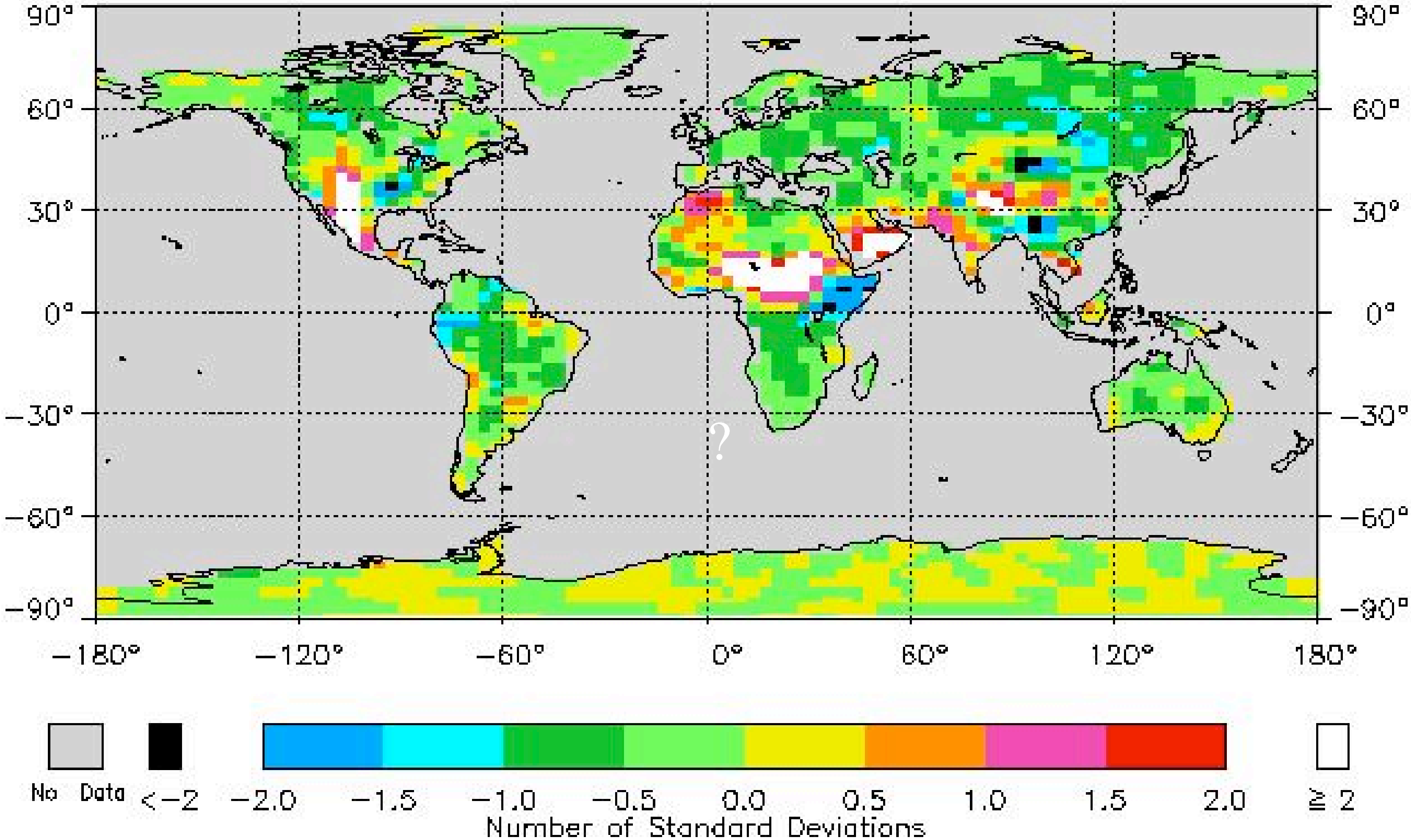
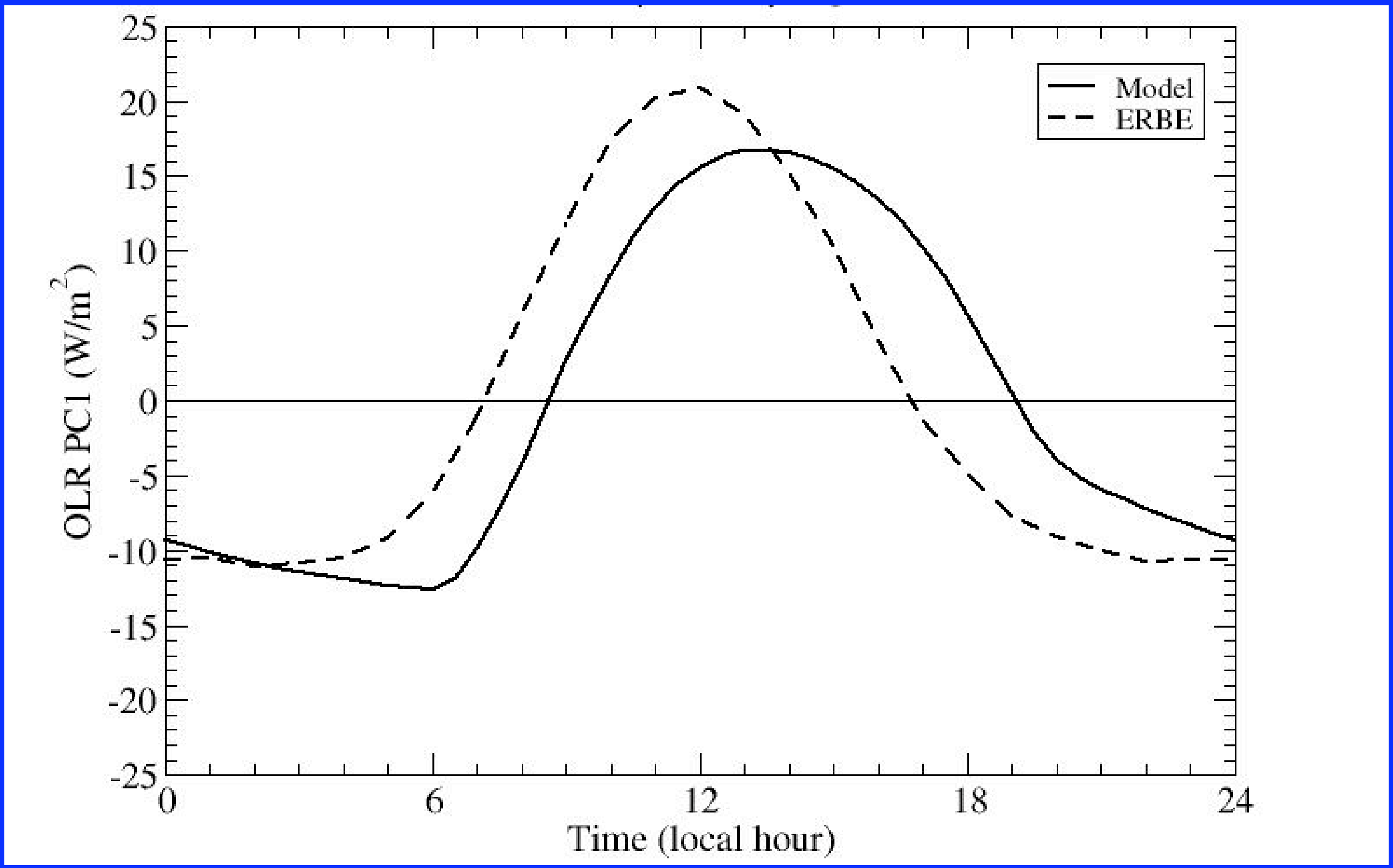
# EOF-1: Land Model



# EOF-2: Land, Model



# Principal Component 1: Land ERBS Comparison

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# Discussion of PC-1, Land, Model vs. ERBS

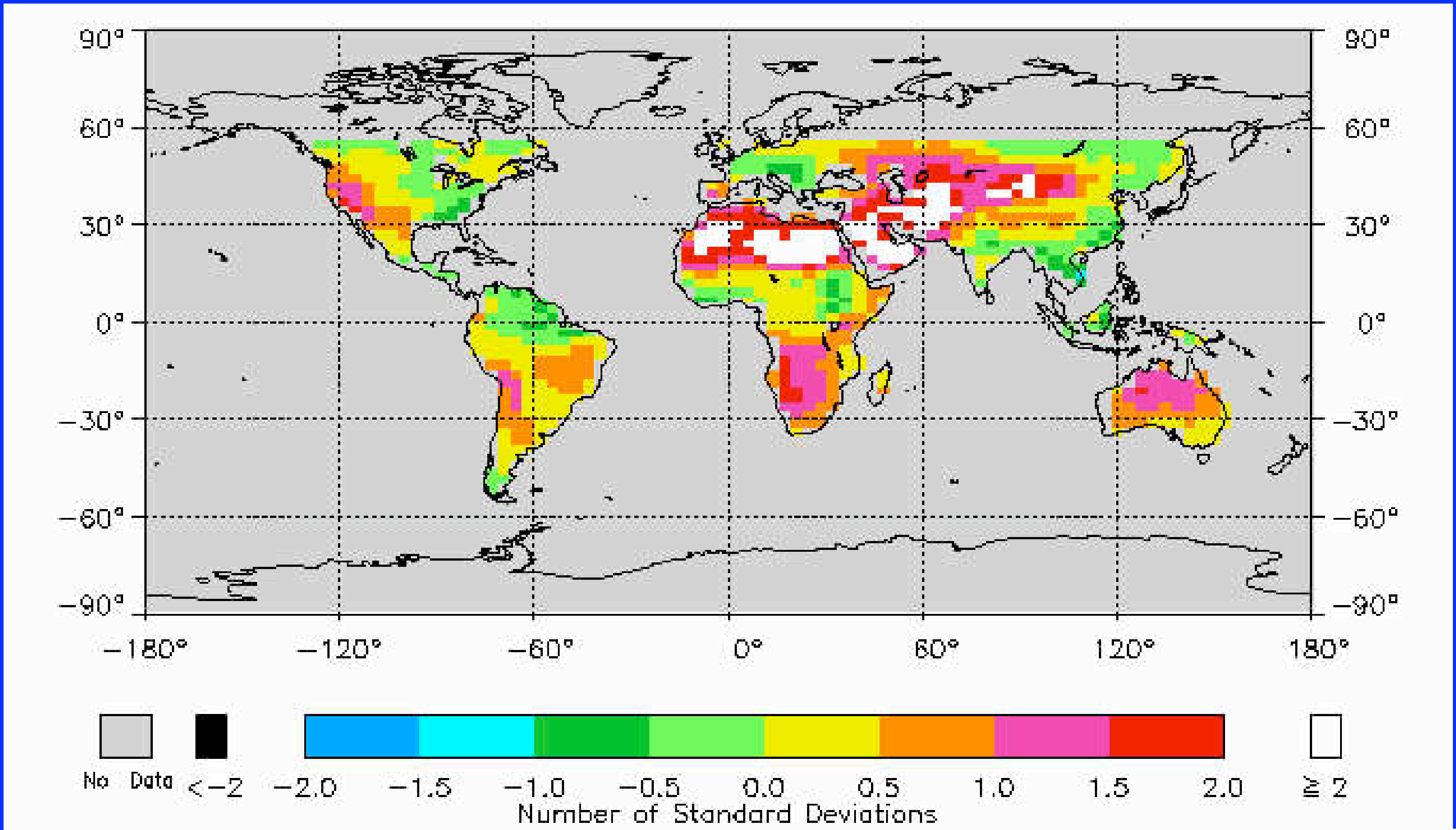
PC-1 compares fairly well, depending on your expectations. The model has an amplitude of about 15 W-m-2, compared to ERBS result of 20 W-m-2.

Whereas ERBS PC-1 is symmetric about noon, the model has a lag as expected, peaking at 1400. Also, ERBS PC-1 is flat at night, which is not intuitive, but Model PC-1 has the expected Cool-down at night.

However, the work of Minnis et al. using GOES window channel shows results similar to the ERBS EOF-1., I.e. a flat diurnal cycle at night.

GERB data will be useful for confirming observations in GERB domain.

# Model EOF-1 Land over ERBS Domain

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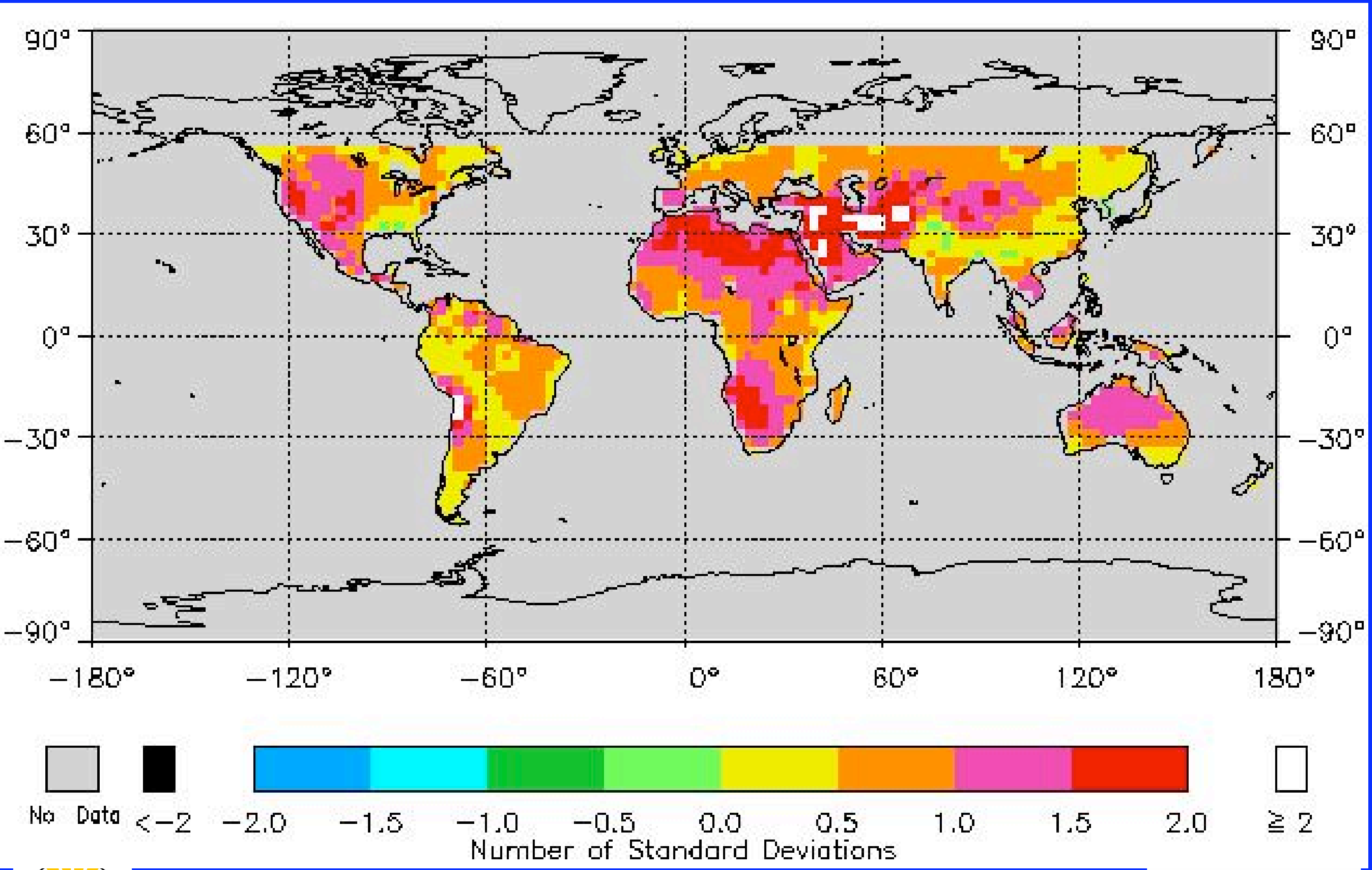
# ERBS EOF-1 Land

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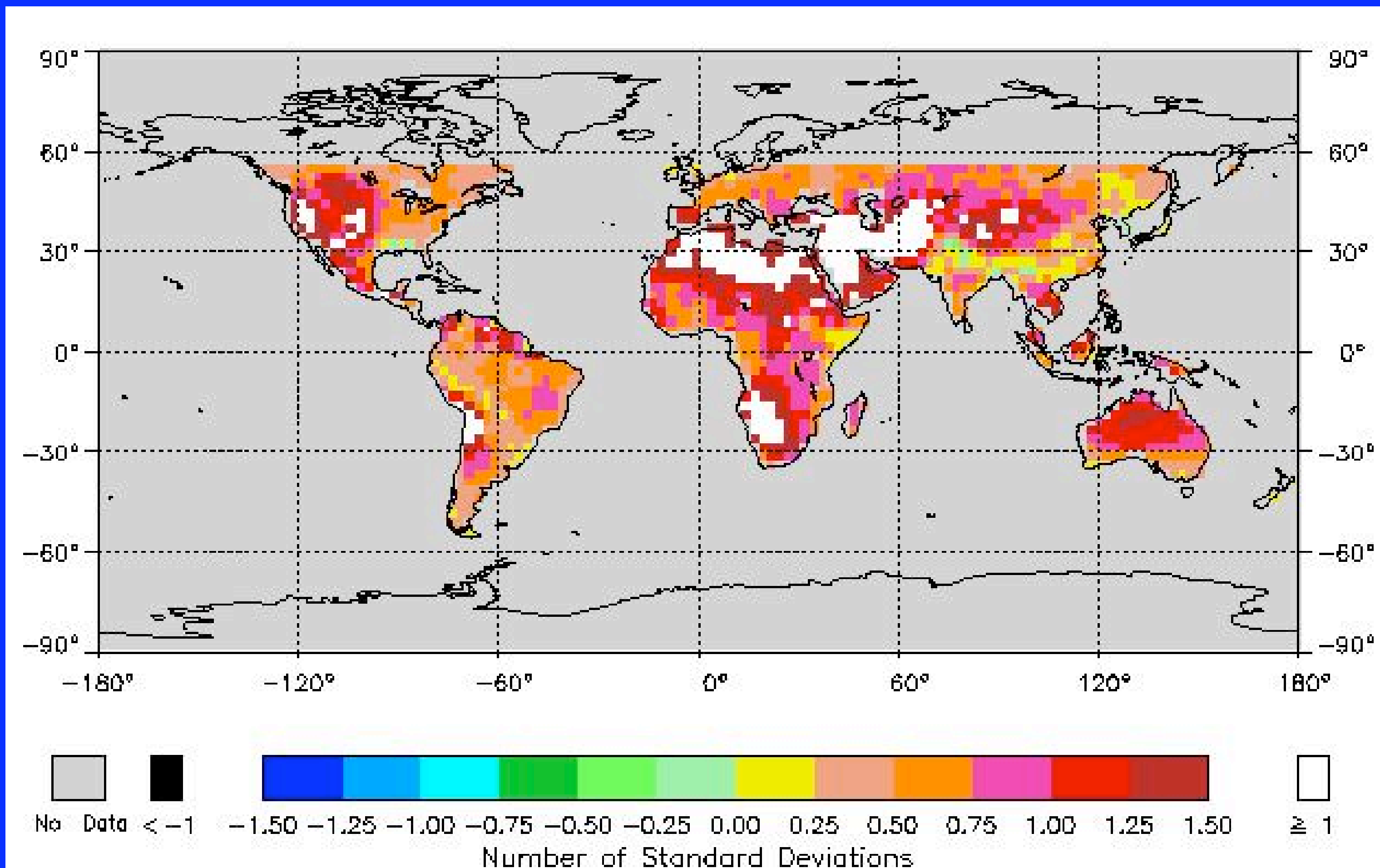
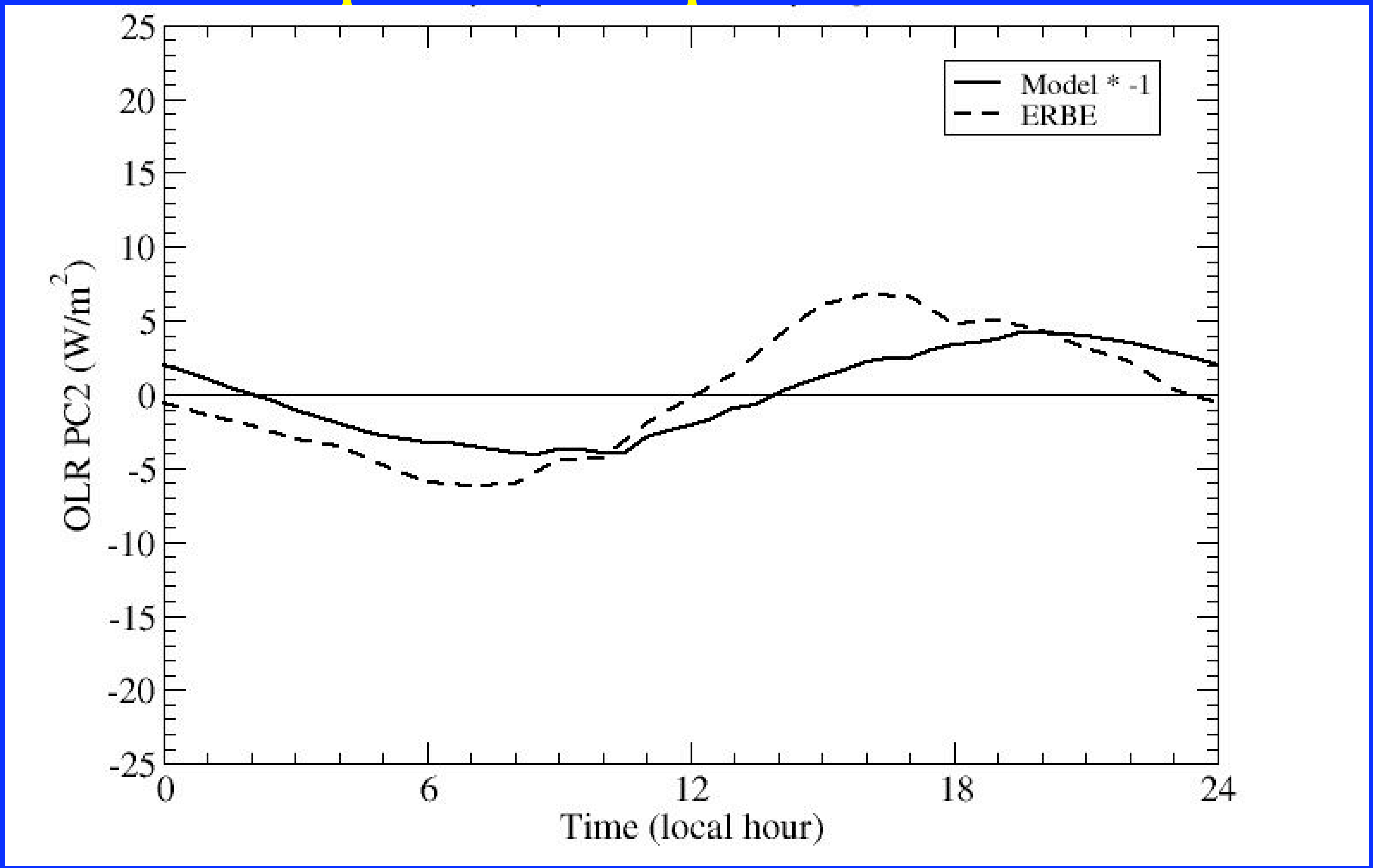
# ERBS EOF-1 Land
# note color bar difference

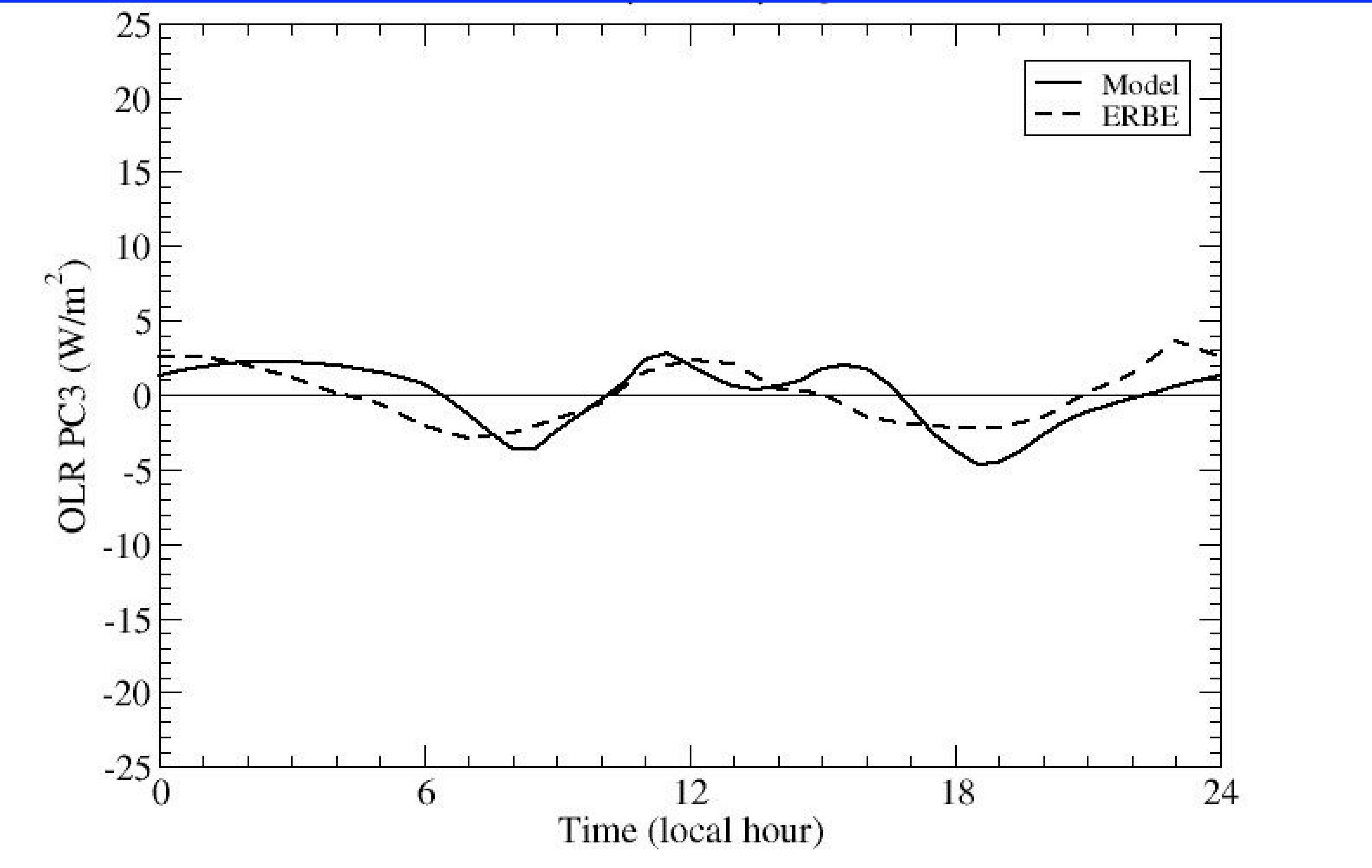


# Principal Component 2: Land




This PC-2 looks good.

# Principal Component 3: Land



# Discussion of PC-2 and –3 for Land

PC-2 for land for model and for ERBS agree well,
Especially considering the differences noted for PC-1
And the fact that for the model PC-2 accounts for only
5.7% of variance compared to 10% for the ERBS PC-2.
However, for in each case the effect is to describe the
lead or lag of a given region compared to the gross
average. thus the similarity of shape is not so surprising.
Likewise, PC-3 are quite similar, if one smoothes out the
Higher order dipsy doodles and regards PC-3 as a Fourier
wave –2.  (putting this in English may help here)

# Variances: Ocean

**Table 1: Variances for Ocean**

| Order | Model, Global, July | Model, ERBS Domain, Summer | ERBS, Summer |
|---|---|---|---|
| 1 | 0.553 | 0.655 | 0.155 |
| 2 | 0.246 | 0.227 | 0.107 |
| 3 | 0.030 | 0.028 | 0.091 |
| 4 | 0.026 | 0.024 | 0.067 |
| 5 | 0.013 | 0.006 | 0.054 |
| Sum, 5 terms | 0.868 | 0.940 | 0.474 |
| RMS, $W\text{-}m^{-2}$ | 4.2 | 4.0 | 5.9 |

# Discussion of Variances for Ocean

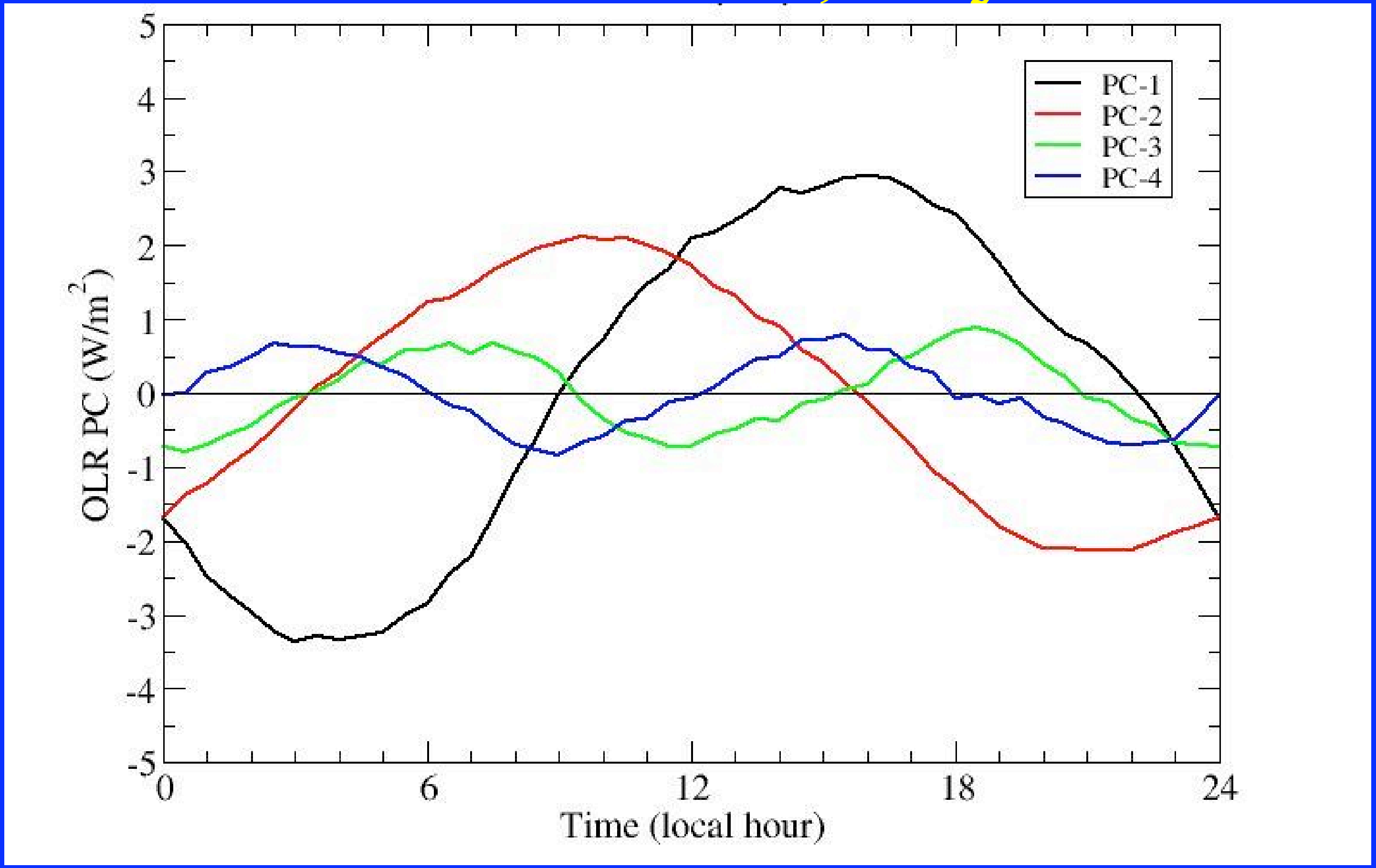
The 1-st 2 patterns of the model account for 80% of the variance, whereas the first 5 patterns of the ERBS account for less than 50%. Thus the observations show much more variety of diurnal cycles over ocean than does the model.

The model shows more variety over the globe than over the ERBS domain, as it should.

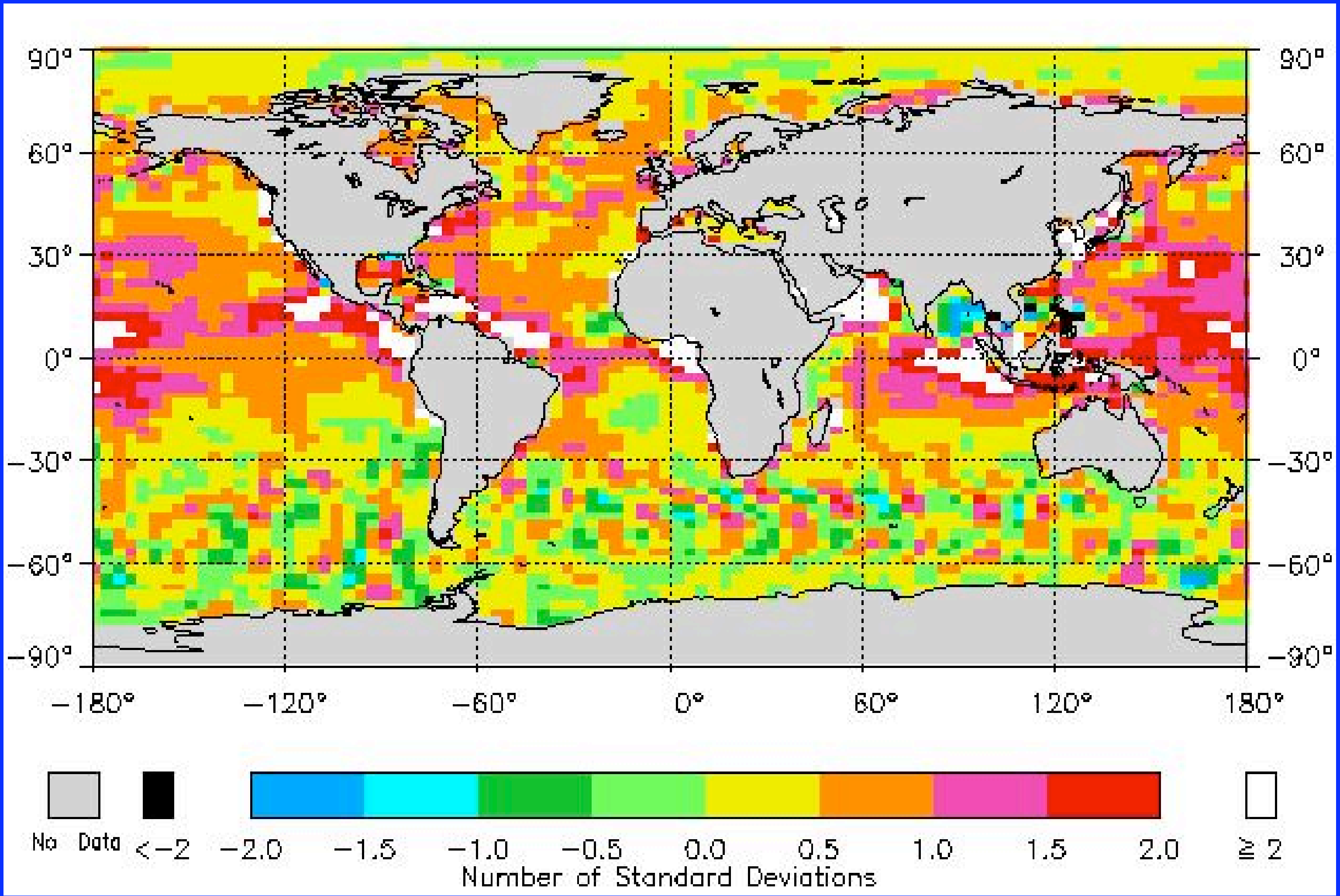
The variance of OLR over ocean is slightly greater over the globe than over the ERBS domain, which is the reverse of that over land.

The variance of the OLR diurnal cycle over ocean is greater in the observations than in the model.

# Principal Components, Ocean: Global Domain, July



# EOF-1: Ocean Model

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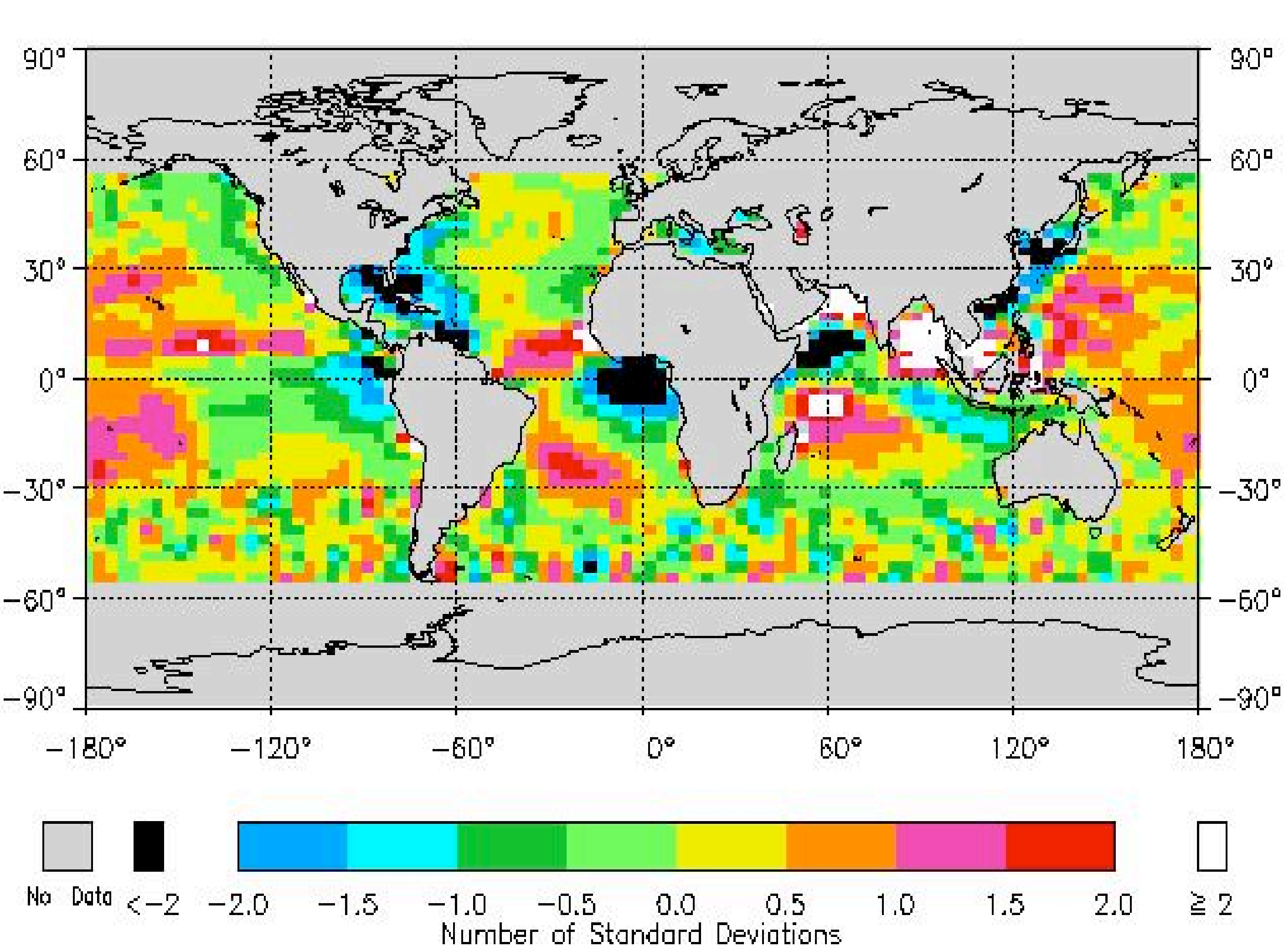
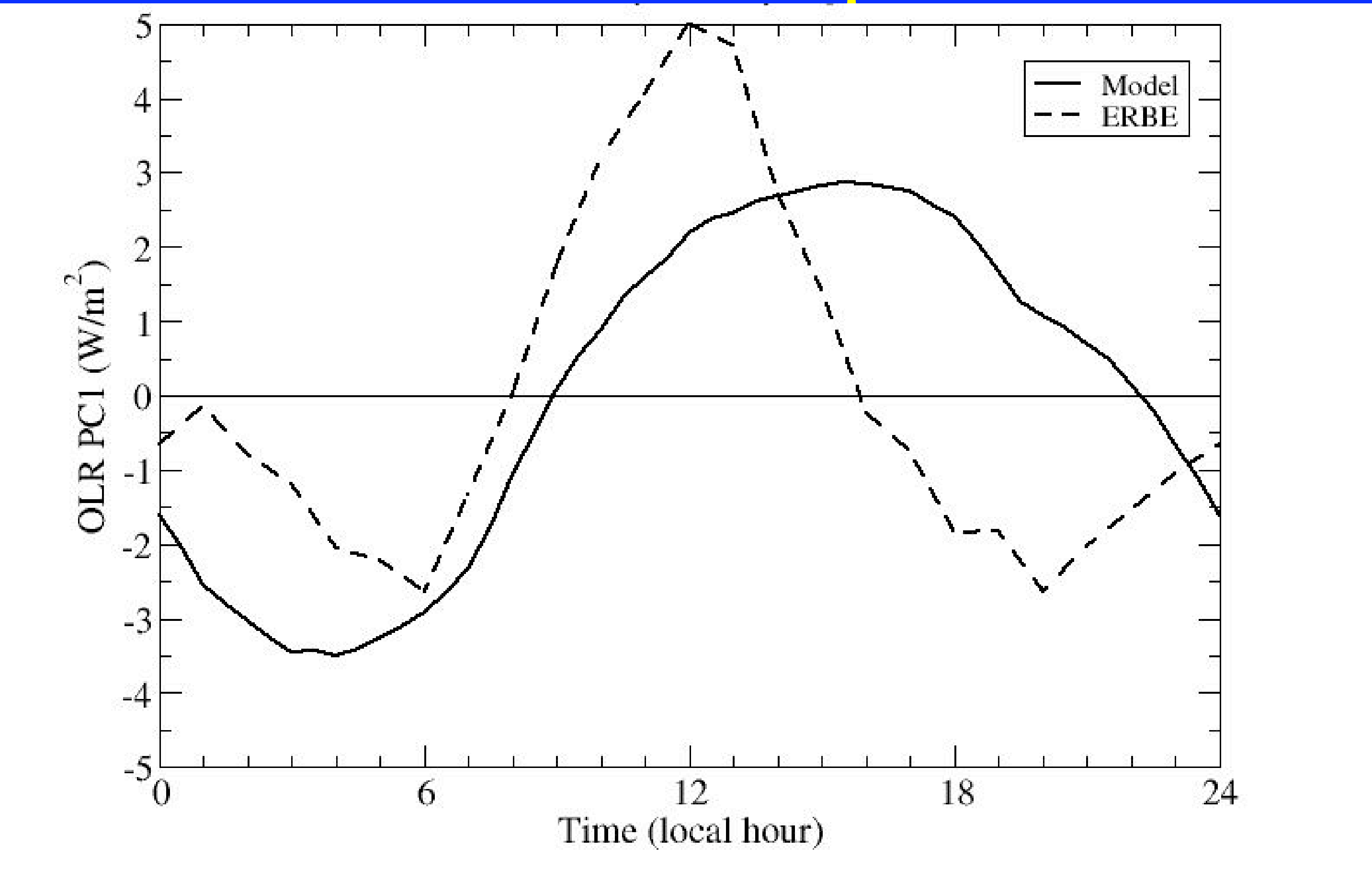
# Discussion of Ocean EOF-1

The Diurnal cycle is strong at low latitudes and decreases with increasing latitude. Reasonable.
There are interesting highs near coasts to explain.
Note The Southern Brazil outflow over the South Atlantic and the West Africa to Amazon connection.
In the roaring 40s there is a wave structure, which I am guessing is an aliasing effect of moving cloud systems into the mean. This is worth looking at. A Hovmueller diagram should be interesting and useful.

# EOF-2: Ocean Model over ERBS Domain



# Principal Component 1: Ocean ERBS Comparison



# Discussion of PC-1, Ocean, Model vs. ERBS

PC-1 for the model is very nearly sinusoidal, with a peak near 1600 hours and minimum near 0400 hours.

For ERBS, PC-1 is a saw-tooth with peak at noon and minima at 0600 and 2000 hours. It is reasonable to ask why the OLR begins to increase at 2000 hours. Then the ERBS OLR decreases from 0100 to 0600.

Because of the thermal mass of ocean, the diurnal OLR variation must be due to clouds and to a lesser degree to the atmospheric temperature profile changing in both model and reality (which is not necessarily the ERBS result, but we hope that we are close).

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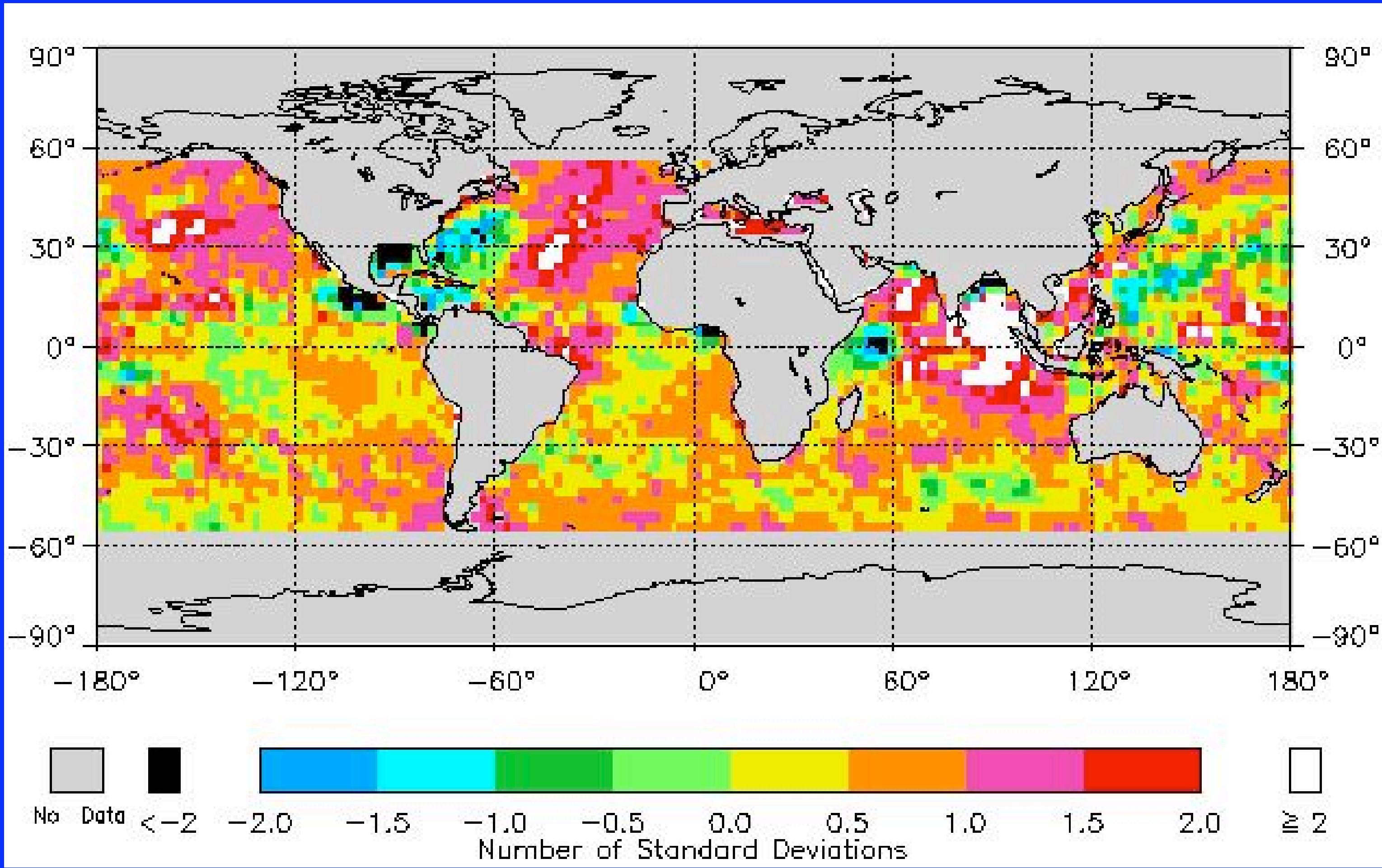
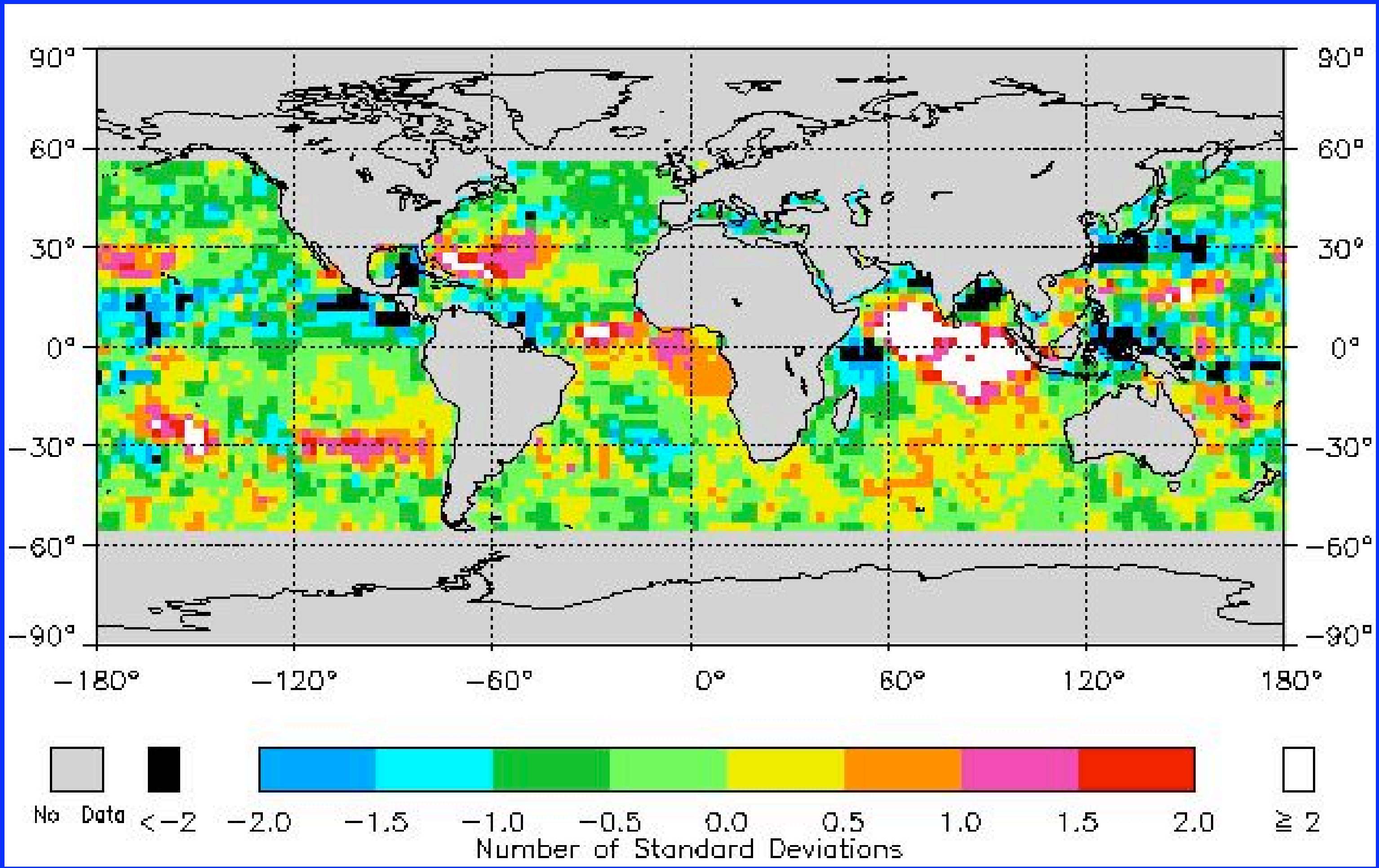
# ERBS EOF-1


90°
60°
30°
0°
−30°
−60°
−90°
−180°
−120°
−60°
0°
60°
120°
180°
No Data
<−2
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
≧ 2
Number of Standard Deviations

# ERBS EOF-2

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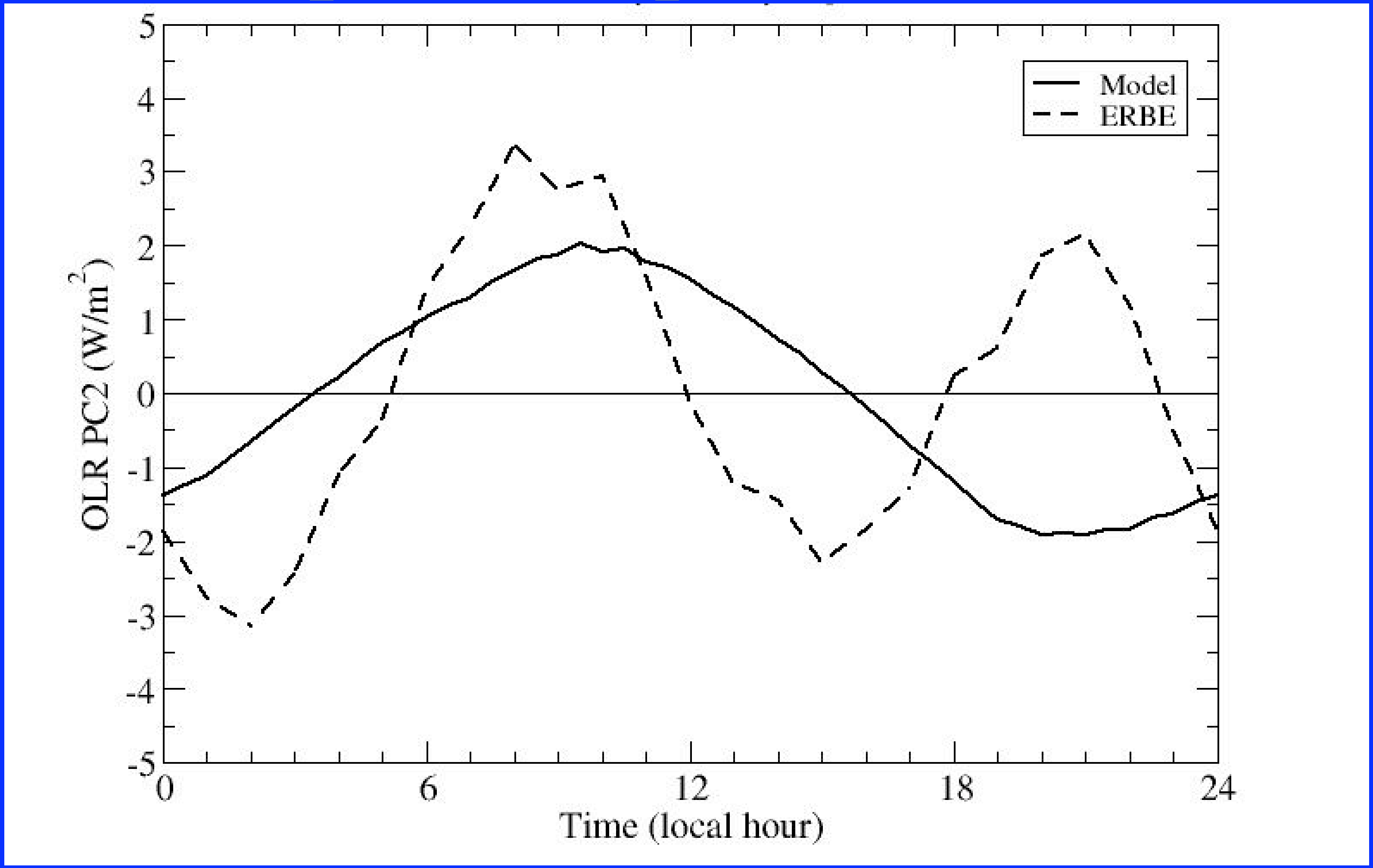
# Principal Component 2: Ocean

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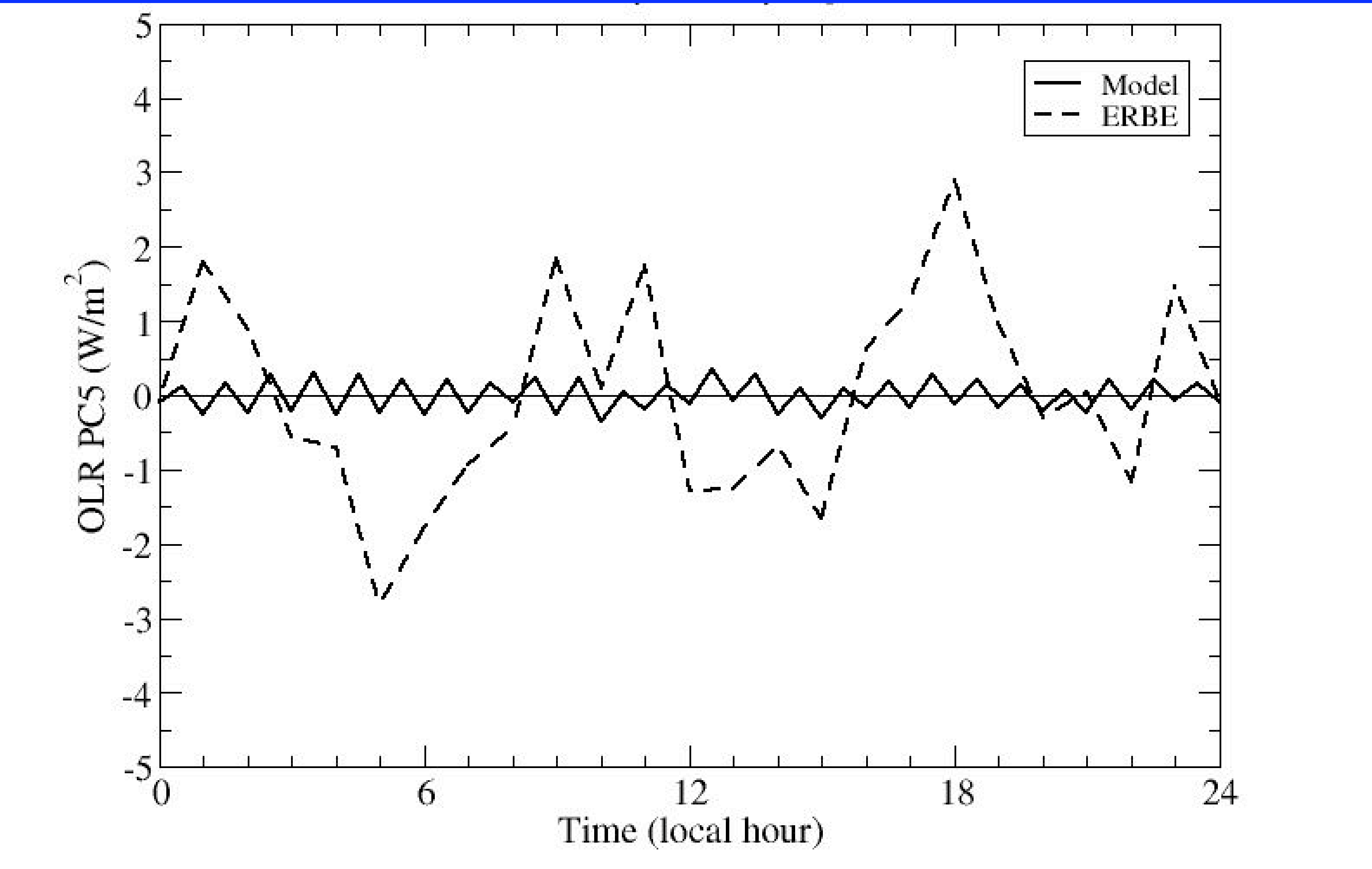
# Discussion of Ocean PC-2

The model PC-2 is a sinusoid $90^{o}$ out of phase with PC-1. The effect is to give a sine wave at each point, with the phase varied by PC-2.
The model results can be duplicated with linear model using a single mass at each grid point, with the mass adjusted to match the phase shift described by PC-2.
The ERBS PC-2 is a wave2. This is a non-linear response of the system to the cycle of solar forcing.
Again, in order to explain the ERBS results, we need to examine cloud data.

# Principal Component 5: Ocean



# Discussion of PC-5 Ocean Comparison of Model and ERBS

The variance of the model is 0.6% and for ERBS is 5.4%, so that ERBS is seeing an order of magnitude more in Pattern 5 than the model generates.

Moreover, the ERBS result has structure which could be physically real, but the model appears to have simply put the noise (sampling of synoptic variations) into this mode.

# Conclusions

## The Method of Principal Component Analysis has been used to compare the Diurnal cycle of OLR as generated by the Unified Model and as measured by ERBS

- Land:
- The RMS of the cycles are comparable.
- PC-1 model and ERBS ranges are very close.
- PC-1 of the model shows cool-down at night and lag from solar heating. These features were not observed by ERBS.
- EOF-1 pattern is reasonable.
- PC-2 and –3 agree fairly well.

# Conclusions

- Ocean:
- The Model RMS is not as large as ERBS observed (4.0 vs. 5.9 W-m-2).
- The model responses are not as varied as ERBS observations.
- The Model PCs are regular Sines, but the ERBS results are more irregular.
- GERB data will be invaluable in resolving questions raised by this study, especially as augmented by SERVIRI.